

Answer the following questions:-

The first question:

- Drive a relation for critical radius of insulation for a cylinder?
- Calculate the critical radius of insulation for asbestos ($k=0.17 \text{ W/m} \cdot ^\circ\text{C}$) surrounding a pipe and exposed to room air at 20°C with ($h = 3 \text{ W/m}^2 \cdot ^\circ\text{C}$), calculate also the heat loss from a 200°C , 5 cm diameter pipe when covered with critical radius of insulation and without insulation.

The second question:

- Explain the theory of fins and why they are widely used in engineering applications?
- Steam in a heating system flows through tubes whose outer diameter is 3 cm and whose walls are maintained at a temperature of 120°C circular aluminum fins ($k=180 \text{ W/m} \cdot ^\circ\text{C}$) of outer diameter 6 cm and constant thickness 2mm are attached to the tube, the space between the fins is 3 mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surrounding air at 25°C with heat transfer coefficient of $60 \text{ W/m}^2 \cdot ^\circ\text{C}$. Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins. (take fin efficiency $=0.95$)

The third question:

- Define the following: blackbody, reflectivity, radiosity, and reradiating surface?
- What is a radiation shield? Why is it used?
- A paint baking oven consists of a long, triangular duct in which a heated surface is maintained at 1200 K and another surface is insulated. Painted panels, which are maintained at 500 K , occupy the third surface. The triangle is of width $w=1 \text{ m}$ on a side, and the heated and insulated surfaces have an emissivity of 0.8. The emissivity of the panels is 0.4. During steady-state operation, at what rate must energy be supplied to the heated side per unit length of the duct to maintain its temperature at 1200 K ? What is the temperature of the insulated surface?

The fourth question:

- What is the lumped system analysis? When is it applicable?
- A long aluminum cylinder 5.0 cm in diameter and initially at 200°C is suddenly exposed to a convection environment at 70°C and $h = 525 \text{ W/m}^2 \cdot ^\circ\text{C}$. Calculate the temperature at a radius of 1.25 cm and the heat lost per unit length 1 min after the cylinder is exposed to the environment. ($k=215 \text{ W/m} \cdot ^\circ\text{C}$, $\rho=2700 \text{ kg/m}^3$ and $c_p=0.9 \text{ kJ/kg} \cdot ^\circ\text{C}$).

The fifth question:

- Drive an expression for the general equation of heat conduction in spherical coordinates?
- A stainless steel sphere ($k = 16 \text{ W/m} \cdot ^\circ\text{C}$) having a diameter of 4 cm is exposed to a convection environment at 20°C , $h = 15 \text{ W/m}^2 \cdot ^\circ\text{C}$ heat is generated uniformly in the sphere at the rate of 1.0 MW/m^3 . Calculate the steady state temperature for the center of the sphere.

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Answer all the following questions

Question (1) (12 Marks)

- 5 a) Derive a relation for critical radius of insulation for a sphere?
- 7 b) An insulated steam pipe having outside diameter of 3 cm is to be covered with two layers of insulation each having a thickness of 2.5 cm. The average thermal conductivity of one material is 5 times that of the other. Assuming that the inner and outer surface temperatures of composite insulation are fixed, how much will the heat transfer be reduced when the better insulating material is next to the pipe than it is outer layer?

Question (2) (12 Marks)

- 4 a) When may one expect radiation heat transfer to be important?
- 4 b) Discuss the mechanism of heat convection?
- 4 c) A very long copper rod [$k=372 \text{ W/m} \cdot ^\circ\text{C}$] 2.5 cm in diameter has one end maintained at 90°C . The rod is exposed to a fluid whose temperature is 40°C and the heat transfer coefficient is $60 \text{ W/m}^2 \cdot ^\circ\text{C}$. How much heat is lost by the rod?

Question (3) (10 Marks)

- 3 a) Define the following: thermal conductivity of a material, thermal contact resistance, and conduction shape factor.
- 7 b) A Consider a large 5 cm thick brass plate ($k = 111 \text{ W/m} \cdot ^\circ\text{C}$) in which heat is generated uniformly at a rate of $2 \times 10^5 \text{ W/m}^3$. One side of the plate is insulated while the other side is exposed to an environment at 25°C with a heat transfer coefficient of $44 \text{ W/m}^2 \cdot ^\circ\text{C}$. Explain where in the plate the highest and lowest temperatures will occur, and determine their values.

Question (4) (12 Marks)

- 4 a) Define irradiation and radiosity?

- ② b) What is Kirchhoff's identity?
- ⑥ c) Two large parallel planes having emissivities of 0.3 and 0.5 are maintained at temperatures of 800 K, respectively. A radiation shield having an emissivity of 0.05 on both sides is placed between the two planes. Calculate (a) the heat-transfer rate per unit area if the shield were not present, (b) the heat-transfer rate per unit area with the shield present, (c) the temperature of the shield.

Question (5) (12 Marks)

- ④ a) What is meant by a lumped capacity? What are the physical assumptions necessary for a lumped-capacity analysis to apply?
- ⑧ b) A short aluminum cylinder 5.0 cm in diameter and 10.0 cm long is initially at a uniform temperature of 200 °C. It is suddenly subjected to a convection environment at 70 °C, and $h=525 \text{ W/m}^2 \cdot ^\circ\text{C}$. Calculate the temperature at a radial position of 1.25 cm and a distance of 0.625 cm from one end of the cylinder 1 min after exposure to the environment; calculate also the heat loss from the cylinder.

Question (6) (12 Marks)

- ④ a) What are the heat exchanger types?
- ④ b) Define the heat exchanger effectiveness, and fouling factor?
- ④ c) A small cubical furnace 50 by 50 by 50 cm on the inside is constructed of fireclay brick [$k=1.04 \text{ W/m} \cdot ^\circ\text{C}$] with a wall thickness of 10 cm. the inside of the furnace is maintained at 500 °C, and the outside is maintained at 50 °C. Calculate the heat lost through the walls.

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Answer all the following questions

Question (1) (15 Marks)

- Derive a relation for critical radius of insulation for a sphere?
- An insulated steam pipe having outside diameter of 3 cm is to be covered with two layers of insulation each having a thickness of 2.5 cm. The average thermal conductivity of one material is 5 times that of the other. Assuming that the inner and outer surface temperatures of composite insulation are fixed, how much will the heat transfer be reduced when the better insulating material is next to the pipe than it is outer layer?

Question (2) (15 Marks)

- When may one expect radiation heat transfer to be important?
- Discuss the mechanism of heat convection?
- Explain the theory of fins and why they are widely used in engineering applications?
- A very long copper rod [$k=372 \text{ W/m} \cdot ^\circ\text{C}$] 2.5 cm in diameter has one end maintained at 90°C . The rod is exposed to a fluid whose temperature is 40°C and the heat transfer coefficient is $60 \text{ W/m}^2 \cdot ^\circ\text{C}$. How much heat is lost by the rod?

Question (3) (15 Marks)

- Heat is uniformly generated inside a solid circular rod by the rate of $q_v (\text{W/m}^3)$. The length of the rod is long enough such that all of the internally generated heat is considered to diffuse to the outer surface of the rod in the radial direction. Starting from the general equation of heat conduction in cylindrical coordinates:

$$\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} + \frac{1}{r^2} \frac{\partial^2 T}{\partial \Phi^2} + \frac{\partial^2 T}{\partial z^2} + \frac{q_v}{k} = \frac{1}{\alpha} \frac{\partial T}{\partial \tau}$$

Deduce an expression for the temperature distribution inside the rod. Schematically draw this distribution and show that the maximum temperature inside the rod is expressed as the following:

$$T_{\max} = T_w + \frac{q_v R^2}{4k}$$

Where, T_w is the outer surface temperature of the rod

R & k are the radius and thermal conductivity of the rod respectively.

- b) An electric wire has a diameter of 10 mm, thermal conductivity of $144 \text{ W/m}^\circ\text{C}$ and electrical resistance of $0.1 \Omega/\text{m}$. The wire is uniformly covered by an insulating layer of 3 mm thickness and $0.15 \text{ W/m}^\circ\text{C}$ thermal conductivity. The wire is used in an environment of temperature 30°C and the heat transfer coefficient from the outside surface of the insulating layer is $86 \text{ W/m}^2^\circ\text{C}$. If the maximum operating temperature inside the wire should not exceed 150°C , what is the maximum safe electric current may flow through the wire?

Question (4) (15 Marks)

- a) Define irradiation and radiosity?
- b) What is Kirchhoff's identity?
- c) Two large parallel planes having emissivities of 0.3 and 0.5 are maintained at temperatures of 800 K , respectively. A radiation shield having an emissivity of 0.05 on both sides is placed between the two planes. Calculate (a) the heat-transfer rate per unit area if the shield were not present, (b) the heat-transfer rate per unit area with the shield present, (c) the temperature of the shield.

Question (5) (15 Marks)

- a) What is meant by a lumped capacity? What are the physical assumptions necessary for a lumped-capacity analysis to apply?
- b) A short aluminum cylinder 5.0 cm in diameter and 10.0 cm long is initially at a uniform temperature of 200°C . It is suddenly subjected to a convection environment at 70°C , and $h=525 \text{ W/m}^2^\circ\text{C}$. Calculate the temperature at a radial position of 1.25 cm and a distance of 0.625 cm from one end of the cylinder 1 min after exposure to the environment; calculate also the heat loss from the cylinder.

Question (6) (15 Marks)

- a) Define the following: thermal conductivity of a material, thermal contact resistance, view factor, and conduction shape factor?
- b) Two concentric cylinders have diameters of 15 and 25 cm and a length of 7 cm. calculate the shape factor between the open ends.
- c) A small cubical furnace 50 by 50 by 50 cm on the inside is constructed of fireclay brick [$k=1.04 \text{ W/m}^\circ\text{C}$] with a wall thickness of 10 cm. the inside of the furnace is maintained at 500°C , and the outside is maintained at 50°C . Calculate the heat lost through the walls.

- 1- Drive an expression for the general equation of heat conduction in spherical coordinates?
- 2- Heat is generated uniformly at a rate of $2.6 \times 10^6 \text{ W/m}^3$ in a spherical ball ($k=45 \text{ W/m} \cdot ^\circ\text{C}$) of diameter 30 cm. the ball is exposed to iced-water at 0°C with a heat transfer coefficient of 1200 W/m^2 . Determine the temperatures at the center and the surface of the ball.
- 3- Define the following: thermal conductivity, thermal contact resistance, critical radius of insulation of a sphere, fin efficiency and fin effectiveness?
- 4- Steam in a heating system flows through tubes whose outer diameter is 3 cm and whose walls are maintained at a temperature of 120°C circular aluminum fins ($k=180 \text{ W/m} \cdot ^\circ\text{C}$) of outer diameter 6 cm and constant thickness 2 mm are attached to the tube, the space between the fins is 3 mm, and thus there are 200 fins per meter length of the tube. Heat is transferred to the surrounding air at 25°C with heat transfer coefficient of 60 W/m^2 . Determine the increase in heat transfer from the tube per meter of its length as a result of adding fins. (take fin efficiency = 0.95)

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- 1- Derive a relation for critical radius of insulation for a sphere.
- 2- An electric wire has a diameter of 10 mm, thermal conductivity of $144 \text{ W/m} \cdot ^\circ\text{C}$ and electrical resistance of $0.1 \Omega/\text{m}$. The wire is uniformly covered by an insulating layer of 3 mm thickness and $0.15 \text{ W/m} \cdot ^\circ\text{C}$ thermal conductivity. The wire is used in an environment of temperature 30°C and the heat transfer coefficient from the outside surface of the insulating layer is $86 \text{ W/m}^2 \cdot ^\circ\text{C}$. If the maximum operating temperature inside the wire should not exceed 150°C , what is the maximum safe electric current may flow through the wire?
- 3- Derive a relation for the efficiency and effectiveness of an insulated tip fin ?
- 4- A furnace wall is made of three layers, one of fire brick, one of insulating brick and one of red brick the inner and outer surfaces are at 870°C and 40°C respectively the respective coefficients of thermal conductivities of the layers are 1, 0.12 and $0.75 \text{ W/m} \cdot \text{K}$ and the thicknesses are 22 cm, 7.5 and 11 cm. assuming close bonding of the layer at their interfaces, find the rate of the heat loss per sq. meter per hour and the interface temperatures

Answer all the following questions

Question (1)

- Define the following: thermal conductivity of a material, thermal contact resistance, and gray body.
- Derive a relation for critical radius of insulation for a cylinder?
- A furnace wall is made of three layers, one of fire brick, one of insulating brick and one of red brick the inner and outer surfaces are at 870°C and 40°C respectively the respective coefficients of thermal conductivities of the layers are 1, 0.12 and 0.75 W/m.K and the thicknesses are 22 cm, 7.5 and 11 cm. assuming close bonding of the layer at their interfaces, find the rate of the heat loss per sq. meter per hour and the interface temperatures.

Question (2)

- What is meant by: fin efficiency, fin effectiveness, overall effectiveness for a finned surface.
- What is a radiation shield? Why is it used?
- A rod containing uniform heat sources per unit volume q_v is connected to two temperatures as shown in the accompanying figure. The rod is also exposed to an environment with convection coefficient h and temperature T_o . Obtain an expression for the temperature distribution in the rod and the heat loss from the rod.

